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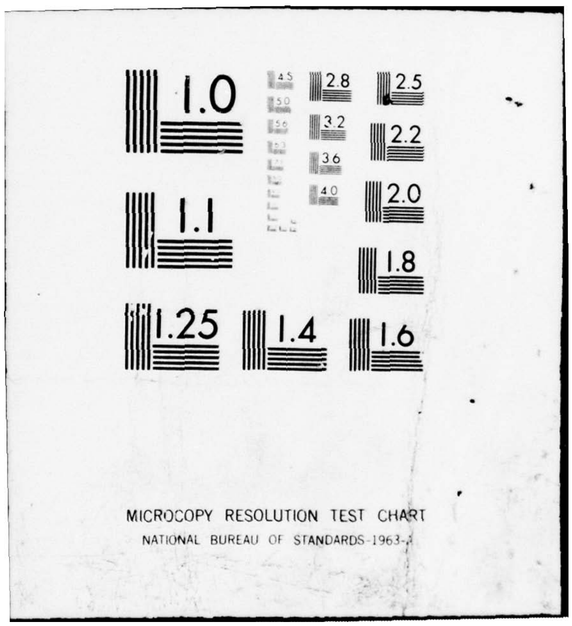
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LONG-RANGE ARTILLERY SOUND RANGING: "PASS" METEOROLOGICAL APPLICATION

SEPTEMBER 1978

By

Abel J. Blanco

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US Army Electronics Research and Development Command
Atmospheric Sciences Laboratory
White Sands Missile Range, NM 88002

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The current field procedure is used to compute artillery sound ranging meteorological (met) messages from the "PASS" met data. Using derived sound ranging data, a review of the met application is included with emphasis on the application to long-range target locations. A sample of the "PASS" sound ranging data is examined and results presented to demonstrate the interactions of the met parameters and the centroid method of sound ranging long-range targets.

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PREFACE

The author gratefully acknowledges the contribution from Mr. William D. Ohmstede and Mrs. Clara B. Anderson for preparation of the "PASS" raw rawinsonde data into a computer format listing the met parameters versus time and space.

CONTENTS

SUMMARY

The computed artillery sound ranging met messages for the PASS experiment are included. The sound ranging met unit effects based on derived timing information and for the surveyed target locations in "PASS" experiment have been discussed. These numbers should be applied with the understanding that the wind correction contains a significant effect on the range component. These unit effects can also be interpreted as the unit expected error of the effective met parameter if it fails to describe the actual effect the sound wave experiences as it travels through the atmosphere. The current field application, i.e., using concept of effective met, yields a "cross-talk" component correction between wind and temperature correction when sound ranging long-range targets. This cross-talk effect describes an area of potential research that could lead to an improvement in met application. Finally, results from a sample of data from the PASS experiment were used to demonstrate the interactions between the wind and temperature and the centroid method of artillery sound ranging. Overall, these results are encouraging because the one probable error is within the accepted 2 percent of target range accuracy.

INTRODUCTION

Atmospheric wind and temperature are well-known parameters affecting the direction and speed of acoustic propagation. Since World War I, sound ranging has been effectively employed by the US Army Artillery to locate enemy targets. The current method uses a linear array of six microphones with a recorder to monitor the sound arrival times at each microphone location. These arrival times are manually selected and provided as input to the computing device. The direction finding procedure depends on the relative arrival times at a pair of adjacent microphones. The intersections of these direction rays are then used to determine the approximate location of the sound source. Wind and temperature corrections are then applied to improve this approximate fix on the real target location.

A Sound Ranging Set Ground Recorder (GR-8) with six microphones was operated during the Atmospheric Sciences Laboratory Meteorological Comparisons (PASS), October - December 1974 [1]. An elaborate assortment of met equipment was assembled at White Sands Missile Range, New Mexico, to collect and process pertinent data. Nine sites simultaneously obtained Ground Meteorological Direction Finder (GMD-1B) rawinsonde data [2]. In addition, other sites collected surface data with remote sensing equipment [3]. Temperature and wind values were continuously recorded at eight levels on a 152-m tower [4].

This technical report presents artillery sound ranging met messages as computed from the rawinsonde data collected during the PASS experiment. Results concerning the interactions between the meteorological conditions and the current method of artillery sound ranging are emphasized. Wind and temperature unit effects for 11- to 16-km ranges and 0- to 25-degree flank angles are presented. The results show that for long-range

targets the present method of met application does not lend itself to improved accuracies in target location. These errors are defined as cross-talk components to wind and temperature corrections. Actual fixes are included to illustrate an apparent biasing effect of the present met correction on longer range fixes.

METEOROLOGICAL MESSAGE

Since the speed of sound is not a fixed value (dependent on meteorological conditions), correction factors are applied to the measured sound ranging arrival times to compensate for the variation of the actual atmospheric conditions from a standard. The standard conditions are defined as the speed of sound being 337.6 m/sec with an effective wind speed of 0 and an effective temperature of 10°C at a height of 200 m above the surface. The first step in met application is to derive the effective met parameter. This parameter describes the resultant effect that the sound wave experiences when traveling from its origin to each microphone location.

The procedure for determining effective temperature is to measure the thermistor temperature from the GMD rawinsonde data and compute the resultant temperature (T_e) as follows:

$$T_e = \frac{3T_v + T}{4} \tag{1}$$

where T equals the thermistor temperature at 200 m level and T_v equals its virtual temperature.

The procedure for determining effective wind direction and speed is to obtain a layered wind profile from the GMD data and combine the weighted values of the surface and the layer winds. These layers represent data at the following levels: 200, 400, 600, and 800 m above the surface. The wind weighting factors corresponding to the measured wind structures are selected from four different weighting factors [5]. The selection of the weighting factors is determined by comparing wind speeds from the surface, 200-, and 400-m levels (see table 1). This procedure was used, and the computed sound ranging met messages from the WSMR met comparison test are included in the appendix. The temperature and wind corrections are then applied to translate the apparent source location closer to its real location.

METEOROLOGICAL APPLICATION

Derived Timing Data

The wind, temperature, and humidity affect the sound wave traveling through the atmosphere. The direction and speed of acoustic propagation are dependent on the met variability. Acoustic propagation may vary significantly from the established standard met conditions. To

demonstrate this meteorological effect on locating a sound source, theoretical arrival times are derived by assuming the source and microphone location and using the speed of sound at standard met conditions. The particular case triangulates on a long-range, 11.5 km, target on the perpendicular bisector (zero flank angle) of the linear microphone array. The direction finding procedure of sound ranging uses the intersection of the direction rays to determine the sound source. The derived data are used to reduce the intersection polygon of error to a single point.

TABLE 1. ARTILLERY METEOROLOGICAL WIND WEIGHING FACTORS FROM FIELD MANUAL

Layer	1	2	3	4
Surface	0.2	0.4	0	0
(m)				
200	0.5	0	1.0	0
400	0.15	0.3	0	1.0
600	0.075	0.15	0	0
800	0.075	0.15	0	0

Weighing factors selected when 400-m layer wind speed is:

1 - 1 to 2 times 200-m layer
2 - over 2 times 200-m layer
3 - less than 200-m layer and within 2 knots of surface
4 - less than 200-m layer and not within 2 knots of surface

Figure 1 illustrates the temperature and wind corrections applied as the met varies above and below the standard. For this case there is a temperature unit effect of 21 m correction for 1°C change in temperature and 18 m correction for 1 knot of crosswind. These unit effects can also be interpreted as the expected error in the effective met parameter when it fails to describe the actual effect the sound wave experiences as it travels through the atmosphere.

A graphical presentation of the met effects was computed by using the current met application [6]. These effects are expressed in the following functional form:

$$\text{Temperature Correction} = \Delta t(T_e/T_{STD} - 1) \qquad (2)$$

$$\text{Wind Correction} = \frac{W}{V^2} S \cos \theta \qquad (3)$$

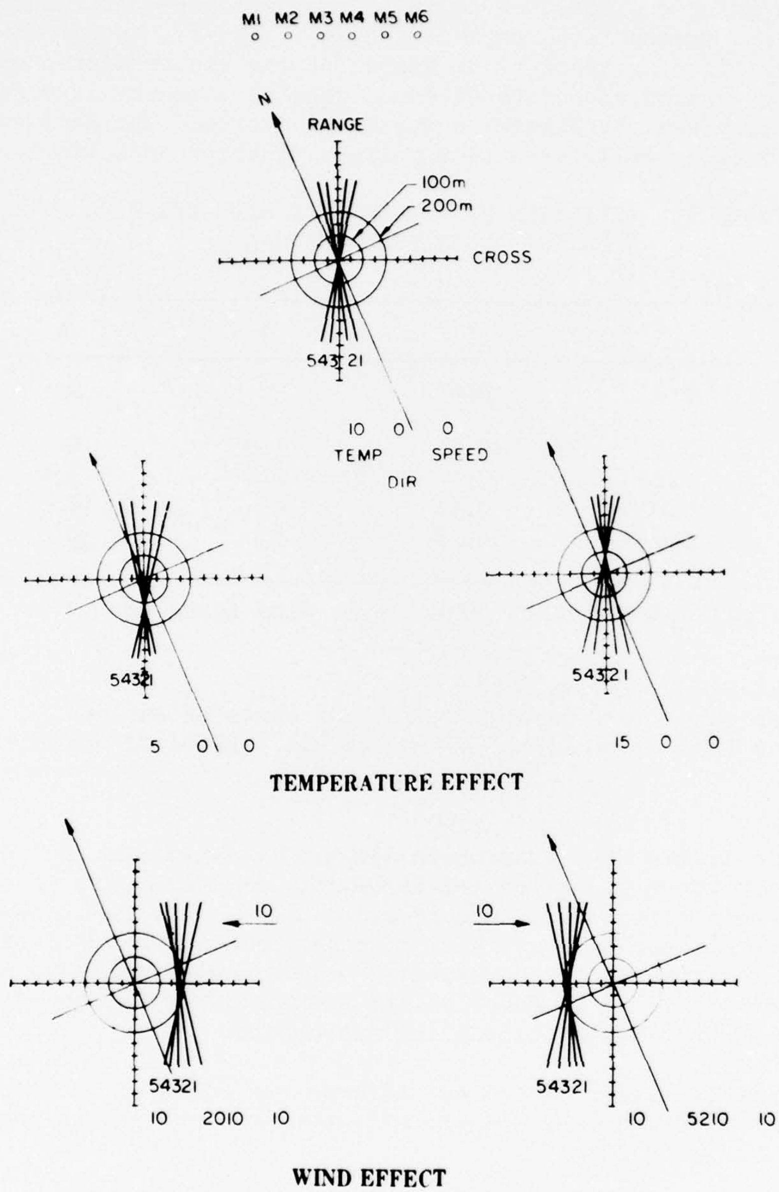

Figure 1. Top intersection locates sound source (11.5 km and 0° flank) under standard conditions; center intersections correct for ±5°C; bottom intersection correct for left/right 10 knots.

where

Δt = relative difference of arrival time from adjacent microphones (sec)

T_e = effective temperature (°K)

T_{STD} = 283.16 (°K)

W = effective wind speed (m/sec)

θ = angle of the effective wind direction with respect to linear array of microphones (deg)

S = distance between adjacent microphones (m)

V = speed of sound (m/sec)

If it is assumed that the gun and all microphones are in the same plane, then the arrival time difference (Δt) between adjacent microphones and the time (t_s) interval between the microphones are formulated

$$\sin \Psi = \frac{\Delta t}{t_s} \quad (4)$$

to compute the direction ray through the sound source being monitored. In fig. 1, direction ray 1 is derived by using data from microphones M1 and M2. The angle Ψ is defined by the direction ray and the perpendicular bisector of line between microphones M1 and M2.

A comparison of the intersection polygon of error for the temperature and wind effect shows that for the wind effect the intersection is not a single point. A review of equation (3) shows that the wind correction is independent of the arrival times. The four-sound-second interval between adjacent microphones and the slope of the microphones determine the wind correction. On the other hand, the polygon of error for the temperature correction [equation (2)], when conditions are perturbed from standard, remains a single point of intersection. Temperatures below the standard will slow the speed of sound and delay the arrival times. Under this condition the sound ranging method will triangulate at a closer target because of the large relative difference between arrival times at adjacent microphones. On applying the correction, the method will adjust the apparent fix to the correct (farther) location. The opposite holds for the high-temperature condition. A point to consider for better understanding the interaction is that the farther the target the less difference in arrival times at the microphone locations. For example, a target at infinity yields constant arrival times at the six microphone locations.

Figure 1 reveals that the temperature correction affects the range component and that the wind correction affects the cross-component. Equation (3) implies that a range wind has no effect because cos θ equals zero; however, the wind correction contains a range component correction that becomes large for long-range targets. This correction is defined as a "cross-talk" component and makes the interpretation of the temperature correction difficult.

In fig. 2 the flank angle in the derived case is increased to 25 degrees. Both met parameters were noted as containing cross-talk effects contaminating the unit effect of the other. The wind polygon of error is shifted to give a large range component correction. This magnitude would mask the temperature effect. The problem needs more investigation to devise a more accurate wind application for long-range targets. A quick-look solution is to apply only the cross-component of the effective wind on each direction ray. This modification would introduce the angle ψ of equation (4) into the wind application, the wind correction thereby having a dependence on the relative difference of arrival times between adjacent microphones.

Unit effects corresponding to target sources used during the PASS experiment and monitored by the artillery sound ranging system are listed in table 2. The current met application was used. The root mean square value is used to represent the effect of each particular parameter. In this manner the range and cross-corrections are included as a radial displacement.

TABLE 2. UNIT EFFECT FOR TEMPERATURE AND WIND CORRECTIONS

Range (km)	Flank Angle (deg)	Temperature (m/°K)	Wind (m/knot)
11.5	0	21	18
11.5	13	25	21
11.5	25	35	35
16.0	9	31	27
16.0	23	38	33

Range and flank angle were selected because of surveyed target locations of the "PASS" experiment. Note that these results are based on derived timing information.

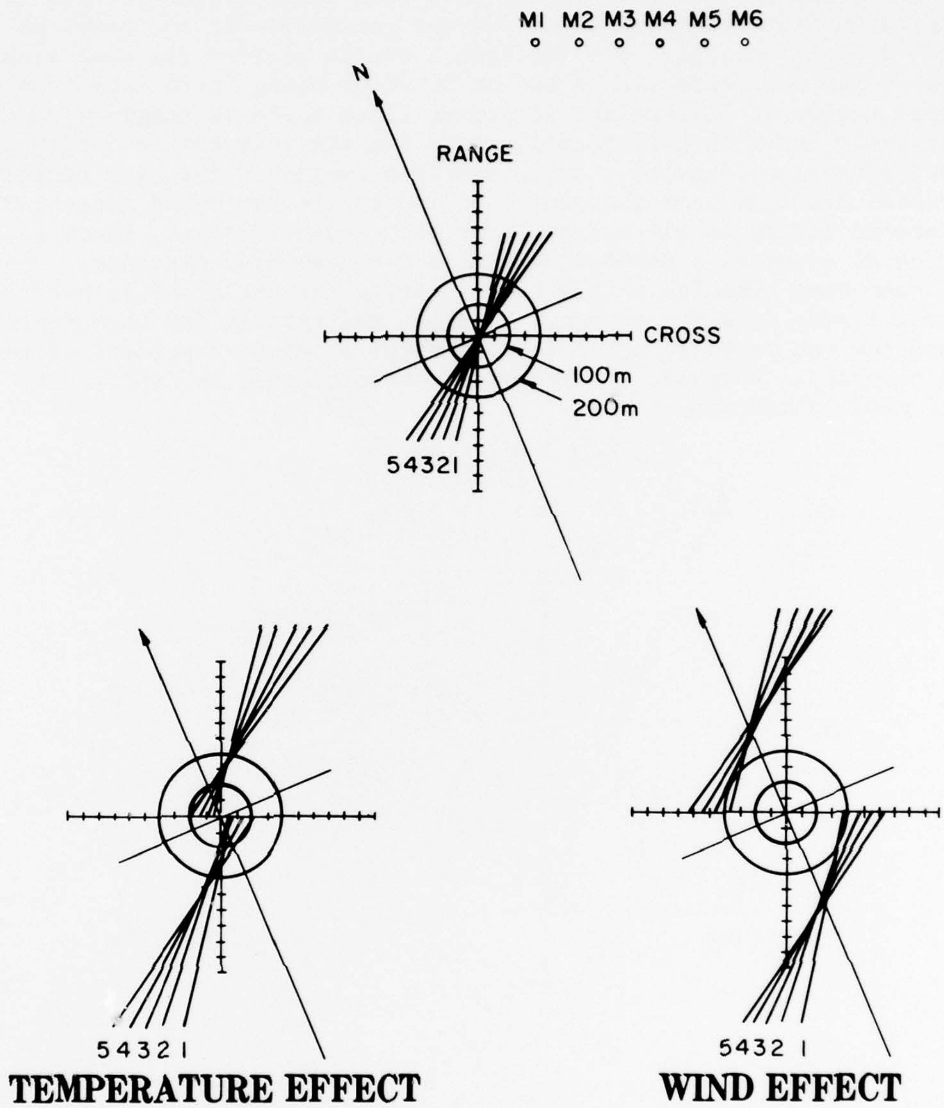

Figure 2. Top intersection locates sound source (11.5 km and 25° flank) under standard conditions; bottom intersections illustrate temperature (±5°C) and wind effects (left/right 10 knots).

PASS Field Data Analysis

Field data from the PASS experiment have been used to present results demonstrating the interactions of the met parameters on the centroid method of sound ranging. Results from a single derived fix have already indicated the unit effects. A set of 54 fixes using field data from a surveyed target at 11.5 km and 13-degree flank angle is examined and the one probable error is used to illustrate the met interaction. Figure 3 indicates the locations of a sound source surveyed at the axis center. The radial distance from the center to a point is the sound ranging miss-distance in fixing on the target. For the cross-component, there is evidence of a normal distribution with a 5-m mean miss-distance. The range component contains a 54-m bias shifting the one probable error dispersion away from the center. Overall, the results are encouraging because the one probable error is within the accepted 2 percent of target range accuracy. However, the accuracy possibly could be improved by better met application.

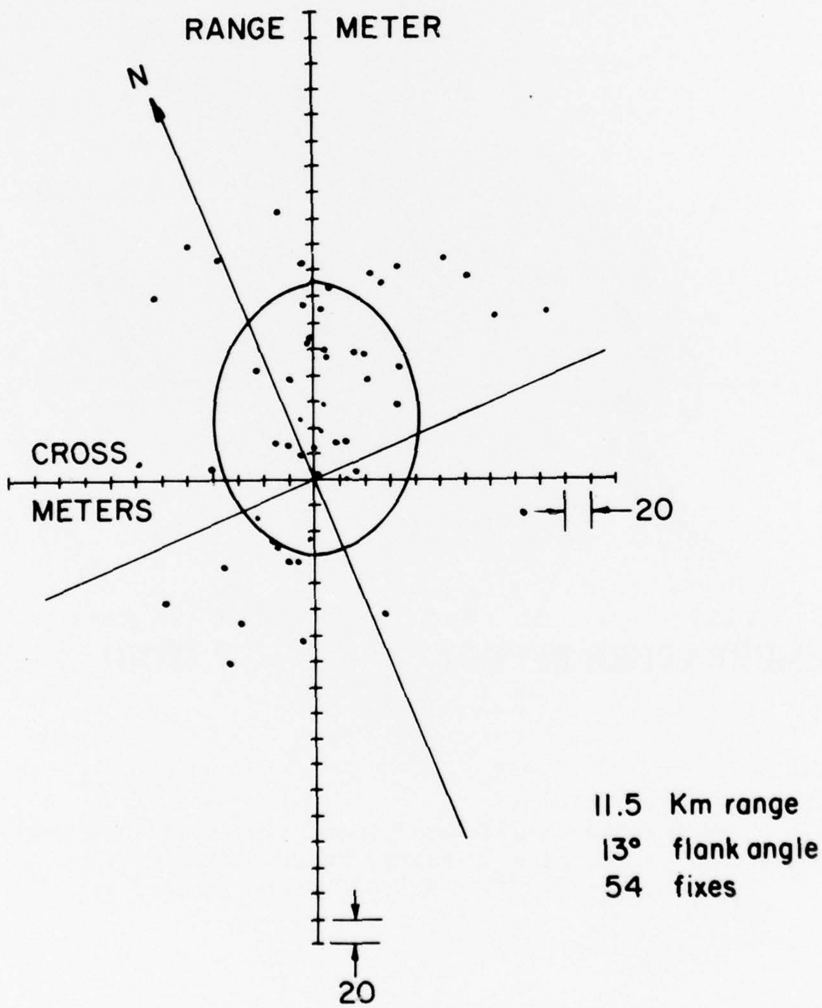

Figure 3. One probable error ellipse derived from 54 fixes on a surveyed "PASS" target of 11.5 km at a 13-degree flank angle.

The next step is to express the met interactions by locating the surveyed target applying one met parameter at a time. If the statistics used to derive the one probable error are compared, the apparent range bias can be accounted for as a result of applying the wind correction. For the sample set of 54 fixes, the current method contains an apparent 54-m bias. If the wind correction is not included, there is a reduction of 18 m with a standard deviation decrease of 3 m. The cross-talk range correction can be significant as previously discussed in the unit effect of a single fix. However, as a group of these 54 fixes there is a 33 percent (18/54) range correction. Table 3 lists the statistics for the sample from the PASS experiment.

TABLE 3. STATISTICS FOR A SAMPLE OF 54 ACTUAL FIXES ON A SURVEYED TARGET AT 11.5 KM AND 13-DEGREE FLANK ANGLE

	Cross Component (m)		Range Component (m)	
	Mean	Sigma	Mean	Sigma
Current met	5	65	54	95
Minus wind	28	69	36	92
Minus wind and temperature	28	69	38	92

These results agree that for the current method the temperature correction contains little effect on the cross-component of locating the target. For these 54 fixes, the temperature correction is small (2 m in the range mean miss-distance). This correction is also confirmed by checking the sound ranging met messages (appendix). The deviation from standard conditions (10°C) is small.

The wind effect in the cross-component is corrected from a 28-m to a 5-m bias, but the range component is increased from 38 to 54 m. This is the primary portion of met application that needs improvement. The wind range effect is masking the temperature effect and one can be misled by applying a different temperature correction to reduce this range bias. The modification to the current wind application that was discussed earlier yields the following statistics: cross-component $\overline{X}$ = 4 m, σ_x = 66 m; range component $\overline{Y}$ = 46 m, σ_y = 89 m. All the "cross-talk" wind effect has not been reduced (54 to 46 m), but results seem favorable for developing better wind applications for long-range sound ranging.

A final point to consider is that the bias errors have not been zeroed because of the time and space variability between the measurement and application of the meteorological conditions, the physical modeling assumption, the errors in met measurements, the choice of timing information picks, and surveyed locations of source point and microphones. Preliminary results from time and space variability indicate that the "cross-talk" of the wind correction on the range component contaminates the temperature effect. This range component effect is dependent on the direction of the wind. A review of figs. 1 and 2 shows that when the wind changes direction the range effect correction also changes signs.

LOCATIONS

Artillery Meteorological Sections (Release Points)	Geodetic Coordinates						WSTM Coordinates*		
	N Latitude			W Longitude			X	Y	Z
	Deg	Min	Sec	Deg	Min	Sec	Ft	Ft	Ft
LC-36 - TSX (31)**	32	24	47.99	106	19	23.73	503,109	189,735	4,033
Orogrande - ORO (38)	32	24	45.46	106	08	50.41	557,402	189,530	4,198
Las Cruces - LSC (15)	32	16	41.73	106	54	48.25	320,713	141,080	4,418
McGregor - MCG (39)	32	16	39.25	106	11	30.58	543,736	140,375	4,097
War Road - WAR (36)	32	17	09.11	106	24	45.93	475,454	143,373	3,986
Small Missile Range - SMR (06)	32	29	00.53	106	25	20.20	472,572	215,268	3,999
Rampart - RAM (37)	32	30	27.89	106	09	50.21	552,221	224,126	4,029
Apache - APA (05)	32	37	37.96	106	23	25.21	482,450	267,552	3,947
Holloman - HMS (01)	32	51	28.56	106	05	36.24	573,682	351,574	4,088

*White Sands Transverse Mercator (WSTM) system. This system is a rectangular modification of the Universal Transverse Mercator (UTM) system designed to minimize earth curvature errors to approximately -1/40,000 at the central meridian and +1/40,000 at 39.6 miles east and west of the central meridian. The origin is the intersection of latitude 38°10'00.000" north and longitude 106°20'00.000" west. The origin has a value of X-500,000.00 feet and Y-100,000.00 feet. X is measured along a line passing through the point in question which crosses the central meridian (longitude 106°20'00.000"W) at a right angle. The value increases positively to the east. Y is measured along the central meridian, increasing in value positively to the north. Z is measured along a radius of the earth at the point in question, above mean sea level (1929 datum), and is expressed in feet increasing positively upward. WSTM can be converted to an approximate UTM system by converting X,Y,Z values to meters.

**The numbers in parentheses are identifiers used in quality control checking of GMD observations.

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APPENDIX
SOUND RANGING MET MESSAGES COMPUTED FOR THE "PASS" EXPERIMENT

Data are listed in the following format: effective temperature (nearest 0.1°C), effective wind direction (tens of mils), and effective wind speed (knots). This is the format currently used for Field Artillery Application. For example the rawinsonde data from station TSX collected on 1 November 1974 at 0355 hours was used to compute the following:

effective temperature = 11.6°C
effective wind direction = 5090 mils
effective wind speed = 5 knots

SOUND RANGING MET MESSAGES

Mo	D	Time	Station	Met Data
11	1	355	TSXFM	116509 5
11	1	355	OROFM	103317 6
11	1	355	MCGFM	10141810
11	1	355	WARFM	108595 1
11	1	355	SMRFM	98 83 3
11	1	425	RAMFM	55 49 2
11	1	425	APAFM	107408 3
11	1	425	HMSFM	10327012
11	1	555	TSXFM	101288 4
11	1	555	OROFM	94528 1
11	1	555	MCGFM	103411 8
11	1	555	WARFM	107480 2
11	1	555	SMRFM	94335 6
11	1	625	APAFM	91406 3
11	1	625	HMSFM	90360 6
11	1	755	TSXFM	8134710
11	1	755	OROFM	104308 5
11	1	755	MCGFM	11139211
11	1	755	WARFM	7940312
11	1	755	SMRFM	79617 1
11	1	825	APAFM	8862014
11	1	835	HMSFM	84294 2
11	2	415	TSXFM	125 5 5
11	2	415	OROFM	135404 6
11	2	415	MCGFM	142553 4
11	2	415	WARFM	97 10 3
11	2	415	SMRFM	120390 3
11	2	445	LSCFM	13542617
11	2	445	HMSFM	136325 7
11	2	615	TSXFM	130359 2
11	2	615	OROFM	122377 2
11	2	615	WARFM	11544210
11	2	615	SMRFM	126197 2
11	2	645	LSCFM	12342615
11	2	645	RAMFM	74466 4
11	2	645	HMSFM	122339 6
11	2	815	TSXFM	132 93 2
11	2	815	OROFM	14333213
11	2	815	MCGFM	166414 6
11	2	815	WARFM	101383 3
11	2	815	SMRFM	119398 7
11	2	845	LSCFM	14343213
11	2	845	RAMFM	105 2 0
11	2	845	APAFM	103320 3
11	2	845	HMSFM	155260 9
11	2	1015	TSXFM	155357 2

Mo	D	Time	Station	Met Data
11	2	1015	OROFM	173354 8
11	2	1015	MCGFM	170413 9
11	2	1015	WARFM	138363 5
11	2	1015	SMRFM	137380 4
11	2	1045	LSCFM	15136013
11	2	1045	RAMFM	122209 2
11	2	1045	APAFM	140352 6
11	2	1045	HMSFM	156314 8
11	2	1215	OROFM	191372 8
11	2	1215	MCGFM	195349 5
11	2	1215	WARFM	17432812
11	2	1215	SMRFM	179314 6
11	2	1245	LSCFM	16339518
11	2	1245	RAMFM	17237310
11	2	1245	APAFM	181378 6
11	4	415	TSXFM	54636 9
11	4	415	OROFM	5963910
11	4	415	WARFM	68 26 4
11	4	415	SMRFM	62 4 6
11	4	445	LSCFM	5863612
11	4	445	RAMFM	90 710
11	4	445	APAFM	70623 9
11	4	445	HMSFM	56 810
11	4	615	TSXFM	61 18 9
11	4	615	OROFM	51640 8
11	4	615	WARFM	41638 6
11	4	615	SMRFM	62 20 7
11	4	645	LSCFM	48 42 6
11	4	645	RAMFM	5162312
11	4	645	APAFM	68564 7
11	4	645	HMSFM	55 31 7
11	4	815	TSXFM	63 21 8
11	4	815	OROFM	78626 5
11	4	815	MCGFM	90640 8
11	4	815	WARFM	62 2011
11	4	815	SMRFM	63 20 4
11	4	845	LSCFM	53 34 3
11	4	845	RAMFM	69631 9
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11	4	845	HMSFM	53 33 4
11	4	1015	TSXFM	76 111
11	4	1015	OROFM	96 4 6
11	4	1015	MCGFM	92628 8
11	4	1015	WARFM	95 42 6
11	4	1015	SMRFM	81 4812
11	4	1045	LSCFM	74575 8

Mo	D Time	Station	Met Data
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11	6 445	OROFM	80 1210
11	6 445	MCGFM	83 85 5
11	6 445	WARFM	85 45 4
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11	6 515	RAMFM	89634 4
11	6 515	APAFM	75630 5
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11	6 645	MCGFM	71 86 8
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11	7 545	WARFM	82 81 5
11	7 545	SMRFM	81 43 1
11	7 615	LSCFM	87150 5
11	7 615	RAMFM	80 86 6
11	7 615	APAFM	67570 5
11	7 615	HMSFM	78 31 4
11	7 745	TSXFM	80 53 4
11	7 745	OROFM	85122 7
11	7 745	MCGFM	126 41 4
11	7 745	WARFM	77 36 6
11	7 745	SMRFM	83494 1
11	7 815	LSCFM	81137 3
11	7 815	RAMFM	76 21 3
11	7 815	APAFM	74483 2
11	7 815	HMSFM	79476 2
11	7 945	TSXFM	99 58 2
11	7 945	OROFM	109 2118
11	7 945	MCGFM	130 69 3
11	7 945	WARFM	95 30 6
11	7 945	SMRFM	96 63 3
11	71015	LSCFM	104164 5
11	71015	RAMFM	128632 7
11	71015	HMSFM	88623 3
11	71145	TSXFM	114629 5
11	71145	OROFM	152 615
11	71145	MCGFM	152 34 4
11	71145	WARFM	122 53 4
11	71145	SMRFM	127 8 1
11	71215	LSCFM	12917411
11	71215	RAMFM	161590 1
11	71215	APAFM	129 55 1
11	71215	HMSFM	117636 1
11	81245	TSXFM	111313 6
11	81245	OROFM	13324612
11	81245	MCGFM	120146 8
11	81245	WARFM	101329 8
11	81245	SMRFM	106325 5
11	81315	LSCFM	10829510
11	81315	RAMFM	133286 5
11	81315	APAFM	117276 8
11	81315	HMSFM	109299 8
11	81445	TSXFM	99294 5
11	81445	OROFM	127290 7
11	81445	MCGFM	14030810
11	81445	WARFM	109310 1
11	81445	SMRFM	110306 5
11	81515	LSCFM	11532810
11	81515	RAMFM	124238 6
11	81515	APAFM	119314 4
11	81515	HMSFM	118339 8
11	81645	TSXFM	12234310
11	81645	OROFM	123362 7
11	81645	MCGFM	123462 3
11	81645	WARFM	131350 8

Mo	D	Time	Station	Met Data
11	8	1645	SMRFM	129297 4
11	8	1715	LSCFM	124314 9
11	8	1715	RAMFM	136330 8
11	8	1715	APAFM	12230310
11	8	1715	HMSFM	12828213
11	11	445	TSXFM	7063314
11	11	445	OROFM	7562617
11	11	445	MCGFM	11161315
11	11	445	WARFM	89 6 7
11	11	445	SMRFM	11462910
11	11	515	LSCFM	106 1215
11	11	515	RAMFM	8061418
11	11	515	APAFM	4361814
11	11	515	HMSFM	10054411
11	11	645	TSXFM	10361813
11	11	645	OROFM	6262412
11	11	645	MCGFM	10961617
11	11	645	WARFM	11219797
11	11	645	SMRFM	93629 6
11	11	715	LSCFM	89 1411
11	11	715	RAMFM	7861415
11	11	715	APAFM	9962314
11	11	715	HMSFM	96 314
11	11	845	TSXFM	9863717
11	11	845	OROFM	9863517
11	11	845	MCGFM	9762613
11	11	845	WARFM	87 3210
11	11	845	SMRFM	113 1917
11	11	915	LSCFM	10661611
11	11	915	RAMFM	13462216
11	11	915	APAFM	9963110
11	11	915	HMSFM	10862614
11	12	415	TSXFM	8524521
11	12	415	OROFM	9422321
11	12	415	MCGFM	94271 9
11	12	415	WARFM	79183 6
11	12	415	SMRFM	93241 7
11	12	445	LSCFM	105 13 1
11	12	445	RAMFM	77236 6
11	12	445	APAFM	101324 7
11	12	445	HMSFM	95360 5
11	12	615	TSXFM	6821314
11	12	615	OROFM	8523312
11	12	615	MCGFM	100377 3
11	12	615	SMRFM	77190 6
11	12	645	LSCFM	96200 2
11	12	645	RAMFM	80258 8
11	12	645	APAFM	86253 4
11	12	645	HMSFM	75340 7
11	12	815	TSXFM	70159 5
11	12	815	OROFM	103372 2
11	12	815	MCGFM	115387 4
11	12	815	WARFM	75605 5
11	12	815	SMRFM	77140 2
11	12	845	LSCFM	93226 2
11	12	845	RAMFM	107278 0
11	12	845	APAFM	75264 2
11	12	845	HMSFM	68361 4
11	14	345	TSXFM	6025914
11	14	345	OROFM	7221616
11	14	345	MCGFM	7824313
11	14	345	WARFM	60164 4
11	14	345	SMRFM	5331513
11	14	415	LSCFM	11427815
11	14	415	RAMFM	73199 8
11	14	415	APAFM	73356 4
11	14	415	HMSFM	55354 8
11	14	545	TSXFM	5526313
11	14	545	OROFM	6022118
11	14	545	MCGFM	6823113
11	14	545	WARFM	68184 9
11	14	545	SMRFM	65334 9
11	14	615	LSCFM	7224414
11	14	615	RAMFM	5924010
11	14	615	APAFM	6432218
11	14	615	HMSFM	4833414
11	14	745	TSXFM	5027311
11	14	745	OROFM	5520917
11	14	745	MCGFM	7323615
11	14	745	WARFM	37226 5
11	14	815	LSCFM	5825814
11	14	815	RAMFM	6823912
11	14	815	APAFM	6130219
11	14	815	HMSFM	38298 8
11	14	945	TSXFM	6425010
11	14	945	OROFM	9324815
11	14	945	MCGFM	7623913
11	14	945	WARFM	68110 5
11	14	945	SMRFM	7434219
11	14	1015	LSCFM	7426511
11	14	1015	RAMFM	7833124
11	14	1015	APAFM	7528614
11	14	1019	HMSFM	70298 6
11	14	1145	TSXFM	87312 8
11	14	1145	OROFM	108186 6
11	14	1145	MCGFM	97234 6
11	14	1145	WARFM	93304 5
11	14	1145	SMRFM	86307 7
11	14	1215	LSCFM	97296 7
11	14	1215	RAMFM	117245 7
11	14	1215	APAFM	78307 8
11	14	1215	HMSFM	99322 8

Mo	D	Time	Station	Met Data
11	15	4 0	TSXFM	92366 4
11	15	4 0	OROFM	91382 5
11	15	4 0	MCGFM	103382 8
11	15	4 0	WARFM	82360 5
11	15	430	LSCFM	85350 5
11	15	430	RAMFM	29359 4
11	15	430	APAFM	83264 5
11	15	430	HMSFM	90276 3
11	15	6 0	TSXFM	88335 6
11	15	6 0	OROFM	77417 2
11	15	6 0	MCGFM	74374 7
11	15	6 0	WARFM	77391 6
11	15	6 0	SMRFM	91365 4
11	15	630	LSCFM	93319 6
11	15	630	RAMFM	68365 6
11	15	630	APAFM	68381 4
11	15	630	HMSFM	91349 3
11	15	8 0	TSXFM	82351 6
11	15	8 0	OROFM	108573 3
11	15	830	MCGFM	105402 9
11	15	8 0	WARFM	57401 1
11	15	8 0	SMRFM	67366 3
11	15	830	LSCFM	114410 6
11	15	830	RAMFM	95402 2
11	15	830	APAFM	68350 2
11	15	830	HMSFM	70286 3
11	15	10 0	TSXFM	100378 4
11	15	10 0	OROFM	129638 4
11	15	10 0	MCGFM	156405 9
11	15	10 0	WARFM	93351 6
11	15	10 0	SMRFM	94307 5
11	15	1030	LSCFM	117412 4
11	15	1030	RAMFM	140471 2
11	15	1030	APAFM	92134 3
11	15	1030	HMSFM	101349 3
11	15	12 0	TSXFM	119446 2
11	15	12 0	OROFM	150370 7
11	15	12 0	MCGFM	172439 6
11	15	12 0	WARFM	160303 8
11	15	12 0	SMRFM	130104 3
11	15	1230	LSCFM	16142911
11	15	1230	RAMFM	153437 3
11	15	1230	APAFM	118272 3
11	15	1230	HMSFM	131336 6
11	18	415	TSXFM	111465 2
11	18	415	OROFM	123278 2
11	18	415	MCGFM	136378 7
11	18	415	WARFM	110424 2
11	18	415	SMRFM	126 9 3
11	18	445	LSCFM	134 837
11	18	445	RAMFM	111362 4
11	18	445	APAFM	114462 3
11	18	445	HMSFM	130327 1
11	18	615	TSXFM	129312 3
11	18	615	OROFM	135324 7
11	18	615	WARFM	117318 3
11	18	615	SMRFM	119320 2
11	18	645	LSCFM	129289 3
11	18	645	APAFM	105284 3
11	18	645	HMSFM	124298 4
11	18	815	TSXFM	128466 2
11	18	815	OROFM	128327 6
11	18	815	WARFM	112507 3
11	18	815	SMRFM	121409 6
11	18	845	LSCFM	136514 5
11	18	845	RAMFM	128367 7
11	18	845	APAFM	118335 7
11	18	845	HMSFM	121307 6
11	19	515	TSXFM	12846517
11	19	515	OROFM	9147119
11	19	515	WARFM	128492 8
11	19	515	SMRFM	15047233
11	19	545	LSCFM	12851017
11	19	545	RAMFM	13546510
11	19	545	APAFM	147468 7
11	19	545	HMSFM	121372 7
11	19	715	TSXFM	123455 3
11	19	715	OROFM	13349533
11	19	715	MCGFM	15047422
11	19	715	WARFM	15262412
11	19	715	SMRFM	15151127
11	19	745	LSCFM	10747215
11	19	745	RAMFM	147520 8
11	19	745	APAFM	13449017
11	19	745	HMSFM	99574 4
11	19	915	TSXFM	14053421
11	19	915	OROFM	148569 7
11	19	10 0	MCGFM	16957116
11	19	915	WARFM	164146 3
11	19	915	SMRFM	14351410
11	19	945	LSCFM	12851716
11	19	945	RAMFM	15955111
11	19	945	APAFM	146566 6
11	19	945	HMSFM	131624 3
11	20	1145	TSXFM	136 56 2
11	20	1145	OROFM	154245 1
11	20	1145	MCGFM	161136 3
11	20	1145	WARFM	141148 9
11	20	1145	SMRFM	142439 1
11	20	1215	LSCFM	136137 7
11	20	1215	RAMFM	165 45 1
11	20	1215	APAFM	132136 2
11	20	1215	HMSFM	135337 6

Mo D Time	Station	Met Data
11201345	TSXFM	162115 4
11201345	OROFM	167394 3
11201345	MCGFM	171 3 2
11201345	WARFM	162126 2
11201345	SMRFM	145146 4
11201415	LSCFM	143171 7
11201415	RAMFM	155627 8
11201415	APAFM	137467 2
11201415	HMSFM	139348 3
11201545	TSXFM	152 2 5
11201545	OROFM	156639 6
11201545	MCGFM	181 10 8
11201545	WARFM	168 20 3
11201545	SMRFM	145 18 2
11201615	LSCFM	157169 7
11201615	RAMFM	154 98 2
11201615	APAFM	144538 4
11201615	HMSFM	148470 4
1123 615	TSXFM	11949820
1123 615	OROFM	13548620
1123 615	MCGFM	14052015
1123 615	WARFM	130557 7
1123 615	SMRFM	12551721
1123 645	LSCFM	9853620
1123 645	RAMFM	12752213
1123 645	APAFM	125598 3
1123 645	HMSFM	114602 6
1123 815	TSXFM	114539 7
1123 815	OROFM	13052113
1123 815	MCGFM	14654428
1123 815	WARFM	122515 7
1123 815	SMRFM	11954010
1123 845	LSCFM	10652620
1123 845	RAMFM	12754611
1123 845	APAFM	11852819
1123 845	HMSFM	89 4 9
11231015	TSXFM	11856913
11231015	OROFM	11655312
11231015	MCGFM	13853514
11231015	WARFM	13455912
11231015	SMRFM	12259212
11231045	LSCFM	12650614
11231045	RAMFM	13762714
11231045	APAFM	119 57 9
11231215	TSXFM	126564 7
11231215	OROFM	136 1 7
11231230	MCGFM	14355810
11231215	SMRFM	127531 9
11231245	LSCFM	11657511
11231245	RAMFM	153514 1
11231245	APAFM	131573 6
11231245	HMSFM	12559411
11231415	TSXFM	120 50 4
11231415	OROFM	12459611
11231415	MCGFM	15161516
11231415	WARFM	13453215
11231415	SMRFM	131 67 7
11231445	LSCFM	12661114
11231445	RAMFM	14663713
11231445	APAFM	15458810
11231445	HMSFM	13160416
11261215	TSXFM	102583 5
11261215	OROFM	128528 4
11261215	MCGFM	137482 7
11261215	WARFM	121241 3
11261215	SMRFM	120 18 4
11261245	LSCFM	117629 3
11261245	RAMFM	132604 7
11261245	APAFM	122636 8
11261245	HMSFM	111541 3
11261415	TSXFM	15060411
11261415	MCGFM	154593 6
11261415	WARFM	144 43 2
11261415	SMRFM	149 38 5
11261445	LSCFM	131170 2
11261445	RAMFM	157602 6
11261445	APAFM	134 64 9
11261445	HMSFM	140594 6
11261615	TSXFM	133 1 6
11261615	MCGFM	160613 6
11261615	WARFM	147 50 5
11261615	SMRFM	138 69 5
11261645	LSCFM	132418 5
11261645	RAMFM	16661811
11261645	HMSFM	145617 8
1127 915	TSXFM	69248 8
1127 915	MCGFM	112271 6
1127 915	WARFM	9325712
1127 915	SMRFM	80290 6
1127 945	LSCFM	71253 8
1127 945	RAMFM	94247 7
1127 945	APAFM	70293 8
1127 945	HMSFM	64343 5
11271115	TSXFM	116470 3
11271115	OROFM	143290 8
11271115	MCGFM	135310 5
11271115	WARFM	114338 8
11271115	SMRFM	10331317
11271145	LSCFM	94285 7
11271145	RAMFM	140261 6
11271145	APAFM	121281 9
11271145	HMSFM	102313 6

Mo D Time	Station	Met Data
11271315	TSXFM	132401 5
11271315	OROFM	14534610
11271315	MCGFM	16434510
11271315	WARFM	13932015
11271315	SMRFM	144335 6
11271345	LSCFM	119315 8
11271345	RAMFM	15734611
11271345	APAFM	14126811
11271345	HMSFM	13330910
12 2 515	TSXFM	68638 5
12 2 515	OROFM	68457 3
12 2 515	MCGFM	111395 4
12 2 515	WARFM	53632 3
12 2 515	SMRFM	58538 1
12 2 545	LSCFM	69489 5
12 2 545	RAMFM	74593 3
12 2 545	APAFM	6648918
12 2 545	HMSFM	76188 1
12 2 715	TSXFM	62 27 6
12 2 715	OROFM	74572 1
12 2 715	WARFM	50 37 2
12 2 715	SMRFM	41545 2
12 2 745	LSCFM	67407 3
12 2 745	RAMFM	66515 2
12 2 745	APAFM	62599 6
12 2 745	HMSFM	82581 5
12 2 915	TSXFM	52 6 4
12 2 915	OROFM	63245 2
12 2 915	MCGFM	85367 6
12 2 915	WARFM	50 43 8
12 2 915	SMRFM	70 67 2
12 2 945	LSCFM	74532 1
12 2 945	RAMFM	61308 4
12 2 945	APAFM	59488 9
12 2 945	HMSFM	57511 1
12 21115	TSXFM	80 11 2
12 21115	OROFM	104550 4
12 21115	MCGFM	129591 2
12 21115	WARFM	94 13 3
12 21115	SMRFM	85636 2
12 21145	LSCFM	88234 4
12 21145	RAMFM	104469 2
12 21145	APAFM	89638 3
12 21145	HMSFM	87271 2
12 21315	TSXFM	106 53 3
12 21315	OROFM	123 42 3
12 21315	MCGFM	147527 4
12 21315	WARFM	126283 2
12 21315	SMRFM	111549 1
12 21345	RAMFM	138 50 4
12 21345	APAFM	116494 3
12 21345	HMSFM	120491 1
12 3 545	TSXFM	74 53 5
12 3 545	OROFM	76343 2
12 3 545	MCGFM	7954312
12 3 545	WARFM	71598 3
12 3 545	SMRFM	52 43 3
12 3 650	LSCFM	86430 3
12 3 615	RAMFM	55200 3
12 3 615	APAFM	65625 4
12 3 635	HMSFM	70102 1
12 3 745	TSXFM	64 35 8
12 3 745	WARFM	57 20 6
12 3 745	SMRFM	60620 5
12 3 815	LSCFM	94328 3
12 3 815	RAMFM	73222 2
12 3 815	APAFM	55606 6
12 3 815	HMSFM	73421 0
12 7 945	TSXFM	72237 8
12 3 945	MCGFM	112299 5
12 3 945	WARFM	65290 1
12 3 945	SMRFM	58 63 5
12 31015	LSCFM	89288 2
12 31015	RAMFM	103197 0
12 31015	APAFM	63100 1
12 31015	HMSFM	65306 5
12 51115	TSXFM	11841820
12 51115	OROFM	14641616
12 51115	MCGFM	13443914
12 51115	WARFM	13043622
12 51115	SMRFM	12147623
12 51145	LSCFM	10048247
12 51145	RAMFM	9742713
12 51145	APAFM	14444514
12 51145	HMSFM	112434 7
12 51315	TSXFM	12049022
12 51315	OROFM	15248117
12 51315	WARFM	13746734
12 51315	SMRFM	13346829
12 51345	LSCFM	107483 6
12 51345	RAMFM	14647514
12 51345	APAFM	13946414
12 51345	HMSFM	14142412
12 51515	TSXFM	13247726
12 51515	OROFM	14445828
12 51515	MCGFM	12048022
12 51515	WARFM	13948033
12 51515	SMRFM	13646518
12 51545	LSCFM	11350223
12 51545	RAMFM	15646721
12 51545	APAFM	13848621
12 51545	HMSFM	13446921

Mo	D	Time	Station	Met Data
12	5	1715	TSXFM	11345922
12	5	1715	OROFM	12047521
12	5	1715	WARFM	10848019
12	5	1715	SMRFM	11445720
12	5	1745	LSCFM	10149331
12	5	1745	RAMFM	11946117
12	5	1745	APAFM	11148829
12	5	1745	HMSFM	127475 9
12	7	515	TSXFM	67638 9
12	7	515	OROFM	43 115
12	7	515	MCGFM	6562310
12	7	515	WARFM	72637 6
12	7	515	SMRFM	6151224
12	7	545	LSCFM	68 1511
12	7	545	RAMFM	39622 7
12	7	545	APAFM	57617 9
12	7	545	HMSFM	53 12 8
12	7	715	TSXFM	54618 9
12	7	715	OROFM	4662212
12	7	715	MCGFM	53 1014
12	7	715	WARFM	56600 4
12	7	715	SMRFM	5561610
12	7	745	LSCFM	36623 5
12	7	745	RAMFM	52602 9
12	7	745	APAFM	56634 8
12	7	745	HMSFM	5163911
12	7	915	TSXFM	56638 8
12	7	915	OROFM	45624 9
12	7	915	MCGFM	80575 6
12	7	915	WARFM	63 20 5
12	7	915	SMRFM	52 13 4
12	7	945	LSCFM	45579 3
12	7	945	RAMFM	71612 9
12	7	945	APAFM	45606 5
12	7	945	HMSFM	69 13 6
12	7	1115	TSXFM	79605 8
12	7	1115	OROFM	83606 7
12	7	1115	MCGFM	86595 5
12	7	1115	WARFM	73237 3
12	7	1115	SMRFM	75265 2
12	7	1145	LSCFM	79481 3
12	7	1145	RAMFM	114599 1
12	7	1145	APAFM	83 25 3
12	7	1145	HMSFM	77627 6
12	7	1315	TSXFM	98437 6
12	7	1315	OROFM	117500 5
12	7	1315	WARFM	106164 4
12	7	1315	SMRFM	9834710
12	7	1345	LSCFM	90409 9
12	7	1345	RAMFM	117383 4
12	7	1345	APAFM	10530310

Mo	D	Time	Station	Met Data
12	7	1345	HMSFM	87425 4
12	7	1515	TSXFM	108256 5
12	7	1315	OROFM	109387 7
12	7	1515	MCGFM	12143719
12	7	1515	WARFM	10639912
12	7	1515	SMRFM	11529811
12	7	1545	RAMFM	113442 5
12	7	1545	APAFM	118198 5
12	7	1545	HMSFM	97366 3
13	7	1545	HMSFM	97366 3

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